These phenomena are not satisfactorily handled by any of the principal theories. They are fairly well explained by the Helmholtz suggestion of shifting color-curves, nearly as well by the hypothesis of Hering and Hillebrand, that color-sensations possess specific brightening or darkening power, which makes itself more notable as the intensity increases. These are but formal explanations, however, and increase rather than diminish the difficulties of the theories to which they are attached.

4. The theory of von Kries, of different visual mechanisms for bright and faint light, supplements excellently the existing theories, and must be regarded as a distinct step in advance.

5. A definite and highly probable function has been assigned to the visual purple, the function of adaptation, and of causing or aiding vision in faint light.

Farther than these at present we can hardly go. The number and variety of known phenomena are great and constantly increasing. Their inter-relations grow every day more complex, and the actual mechanism governing those relations still remains almost entirely unknown. Subjective experiment appears likely to yield little more aid. The various theories have arrived at such a state of perfection, and, thanks to subsidiary hypothesis, to such a state of flexibility, that almost any visual result might probably be explainable by either. Perhaps the most hopeful line of research is that which, like König's study of the visual purple, seeks to find some relation between color-sensations and physical properties. Since so many phenomena point to photo-chemical changes in the eye, it would not be surprising if the next advance should come from the chemical side, rather than from the physiological, physical or psychological, which have held the field so long.

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*A HALF-CENTURY OF EVOLUTION, WITH SPECIAL REFERENCE TO THE EFFECTS OF GEOLOGICAL CHANGES ON ANIMAL LIFE (III.).**

4. THE UPPER CRETACEOUS REVOLUTION.

ANOTHER profound and epoch-making change occurred at the beginning of the Upper Cretaceous. In Eurasia, as Kayser states, "this was one of the greatest changes in the distribution of land and water over almost the whole earth that is known in geographical history. Extensive areas which had for long periods been continents were now overflowed by the sea and covered with Cretaceous deposits;" the Upper Cretaceous strata in certain areas in Germany and Belgium resting directly on archean rocks. In America (the Dakota stage) there was also a great subsidence. The Atlantic coastal plain was submerged over what was Triassic soil, also the lowlands from New Jersey through Maryland to Florida, while the Gulf of Mexico extended northward and covered western Tennessee, Kentucky and southern Illinois; a wide sea connected the Gulf of Mexico with the Arctic Ocean, and thus the North America of that time was divided into a Pacific and an Atlantic land, the latter comprising the Precambrian and Paleozoic areas.

As Scott states: "The Appalachian mountains, which had been subjected to the long-continued denudation of Triassic, Jurassic and Lower Cretaceous times, were now reduced nearly to base-level, the Kittatinny plain of geographers. The peneplain was low and flat, covering the whole Appalachian region, and the only high hills upon it were the mountains of western North Carolina, then much lower than now. Across this low plain the Delaware, Susquehanna and Potomac must have held very

* Address of the Vice-President before Section F—Zoology—of the American Association for the Advancement of Science, August, 1898; concluded from SCIENCE, September 2d.

much their present courses, meandering through alluvial flats" (p. 481). An elevatory movement began in the succeeding or Colorado epoch, and this was succeeded by an uplift on the Atlantic and Gulf coasts, and the continued upheaval in the interior resulted in the deposition of the Laramie brackish and fresh-water beds. There were similar widespread subsidences and upheavals in South America, the Andean chain being in large part upheaved at the close of the Cretaceous.

In the Cretaceous period there were such differences in the distribution of the fossils as to lead Römer, from his explorations in Texas as early as 1852, to consider that the resemblance of the fossils of Texas, Alabama and Mexico, with the West Indies and Colombia, to those of southern Europe were due to differences of climate, a view reiterated by Kayser (p. 283). Scott also states that the Lower Cretaceous beds of Texas show faunal resemblances which ally them to the Portugal and Mediterranean beds, while the faunal relations of South American Lower Cretaceous strata are closely like those of northern and western Africa.

The biological changes at the beginning of the Upper Cretaceous were correspondingly notable. Vast forests of conifers, palms, and especially of deciduous trees, such as the oak, sassafras, poplar, willow, maple, elm, beech, chestnut and many others, clothed the uplands, while in the jungles, on the plains and in the openings of the forests gay flowers bloomed. The flora must even then have been, comparatively speaking, one of long existence, because highly differentiated composite plants, like the sun-flower, occur in the Upper Cretaceous, or Raritan clays, of the New Jersey coast. It may be imagined that, with this great advance in the vegetation, the higher flower-visiting insects must have correspondingly multiplied in number and variety.

While the changes of level did not affect the abysses of the sea, the topography of the shallows and coast was materially modified, and to this was perhaps largely due the extinction of the ammonites and their allies.* It is not impossible that the uncoiling of the ammonites into forms like Scaphites, Crioceras, Helioceras, Turrilites and Baculites were originally perhaps distortions due to physical causes somewhat similar to those which produced a loosening or uncoiling of the spire in Planorbis. These variations or distortions of the pond snail, signs of weakness, the result either of pathological conditions or of senility, were due to unfavorable changes in the environment, such as either a freshening of the

*After preparing this address I find that Wood thirty-six years ago more fully discussed this matter and mentioned the same cause I have suggested. "This disappearance," he says, "of the Ammonitidæ and preservation of the Nautilidæ we may infer was due to the entire change which took place in the condition of the shores at the close of the Cretaceous period; and this change was so complete that such of the shore followers as were unable to adapt themselves to it succumbed, while the others that adapted themselves to the change altered their specific characters altogether. The Nautilidæ having come into existence long prior to the introduction of the Ammonitidæ, and having also survived the destruction of the latter family, must have possessed in a remarkable degree a power of adapting themselves to altered conditions." On the other hand, the dibranchiate cephalopods (cuttles or squids), living in deeper water, being 'ocean rangers,' were quite independent of such geographical changes. Wood then goes on to say that the disappearance of the tetrabranchiate group affords a clew to that of the Mesozoic saurians, and also of cestraciont sharks, whose food probably consisted mainly of the tetrabranchiate cephalopods. "Now the disappearance of the Tetrabranchiata, of the cestracionts and of the marine saurians was contemporaneous; and we can hardly refuse to admit that such a triple destruction must have arisen either from some common cause or from these forms being successively dependent for existence upon each other." He also suggests that the development of the cuttles 'has been commensurate with that of the cetacean order, of some of which they form the food.' (*Phil. Mag.*, XXIII., 1862, p. 384.)

water or some other chemical alteration in the relative amount of alkalines and salts. The changes in the ammonites, though more remarkable, are similar to the aberrations observable in the shells of the upper and later layers of the Steinheim deposits, made known to us by Hilgendorf, Sandberger, and more especially by the detailed and masterly researches of Professor Hyatt.

In this case the Miocene Tertiary *Planorbis lævis* was supposed to have been carried into a new lake, before untenanted by these shells. Although from some unknown cause the lake was unfavorable to the production of normal *lævis*, whose descendants show the results of accidents and disease, yet, owing to isolation, which prevented intercrossing with the present stock, and to the freedom from competition, the species was very prolific, and the lake became stocked with a multitude of more or less aberrant forms constituting new species. Some of them are nearly normal, with a flat spire; others are trochiform, and others entirely unwound or corkscrew-shaped. Similar aberrations occur in *Planorbis complanatus*, living in certain ponds in Belgium (Magnon); in the slightly twisted Planorbid, *Helisoma plexata* Ingersoll of St. Mary's Lake, Antelope Park, Colorado, and in the unwound forms of Valvata first found by Hartt in Lawlor's Lake, near St. John, New Brunswick, and described by Hyatt.* In all these cases of parallelism or convergence the aberrations seem to have been due to some unusual condition of the water adverse to normal growth. Hence it is not impossible that the singular uncoiled or straight forms assumed by certain of the ammonites when on the verge of extinction were likewise cases of convergence and due to weakness or senility, or at least to an unusual and unfavorable condition of the seas in which they lived.

*Annual Report of Hayden's U. S. Geol. and Geogr. Survey of the Territories.

The physical causes of extinction of the Mesozoic reptiles may also have been due to or connected with the changes of coast level, although signs of weakness and senility are exhibited by these. In the Como or Atlantosaurus beds referred by Scott to the Lower Cretaceous rather than Jurassic, the ichthyosaur (*Sauranodon natans*) was toothless, while the colossal Cretaceous pterodactyle, Ornithostoma (Pteranodon), was entirely toothless.

The colossal Pythonomorpha, offshoots of terrestrial lizards, but with paddles adapting them for marine existence, succeeded the plesiosaurs, and may have materially aided in their extinction. Hence arises the question: Did the extinction of the marine reptiles result in or contribute to the great increase of teleost fishes?

Before the dinosaurs began to die out the type in part became specialized into lizard-like tree-climbing forms and agile bird-like forms. The first birds of the Cretaceous were toothed, carinate, highly predaceous forms, with a retrogressive side-branch of wingless diving birds, represented by the colossal Hesperornis, but in this case the loss of teeth was undoubtedly a gain to the type, compensation for the lack of a dental armature in the seed-eating birds being shown in the elaboration of a gizzard.

5. GEOLOGICAL CHANGES IN THE TERTIARY.

Here again we have, as in former periods, a succession of earth-movements, subsidences in one region and elevations in another, though apparently more limited in extent than before, the oscillatory movements being rather confined to coastal areas, and involving adjacent shallow seas, there being frequent alternations of marine with brackish and fresh-water beds. As Kayser remarks, the Tertiary deposits "no longer extended unaltered over whole countries like those of older systems, but generally occupied only smaller basins or bay-

like areas, filled up inland seas or shallow gulfs" (p. 328). Towards the close of the Tertiary the great mountain ranges of Asia and Europe, the Alps, Pyrenees, Caucasus, Himalayas, as well as the Atlas, and the Cordillera of North and South America, were upheaved. The old Tertiary nummulitic beds were, in the western Alps, raised to a height of 11,000 feet, and the Himalayas to a horizon 16,000 feet above the sea, while there were corresponding elevations in western North America and in the Rocky Mountain region.

The evidence from fossils show, what has not been disputed, that the climatic zones were by this time established. In Europe the older Tertiary was decidedly tropical, in the Miocene subtropical, but the climate of Europe was somewhat lowered late in the Miocene, as shown by the absence of palms.* At the end of the Tertiary, *i. e.*, during the Pliocene the earth's climate was but slightly warmer than at present. It should here be noticed that while Greenland, Iceland, Spitzbergen and Grinnell Land under 81° north latitude were during the late Tertiary 'abnormally warm' the Tertiary floras of northeastern Asia, including those of Kamtschatka, Amurland and Saghalien and that of Japan, 'show no sign of a similar warmth, but rather point to a climate colder than that of the present day' (Kayser, p. 354).*

The Tertiary was apparently also a time of more or less inter-continental migrations or interchange of life-forms, which crossed the oceans over so-called continental bridges. Bering Strait was at one time such a bridge, and to explain the geographical distribution of certain forms there is thought to have been a more or less continuous land-connection between India and Africa, and between Africa and South America, and possibly in the Eocene between Australia and southwestern Asia.

However hypothetical these continental bridges may be, we do know that Central America and the Isthmus of Panama were elevated at the end of the Miocene, and that the bridge thus formed between North and South America became an avenue for the interchange of mammals and other animals which materially modified the distribution of life in the southern and northern parts of our continent.

*Jaeger suggests that the occurrence, in the later geological periods, of warm-blooded vertebrates, protected by feathers or hair, was due to the fact that the earth then became cooler than in the preceding ages. His explanation of the origin of feathers and hair is as follows: "If the average temperature of an animal body is considerably higher than that of the surrounding media, oscillations of these media have a stimulating effect upon the skin of the animal. This leads to a tendency to form papillary chorian (*sic*) cells, and these afterwards produce hair or feathers, which represent two of the most characteristic features of warm-blooded animals. He adds that this "stimulatory effect upon the skin can only be due to low temperatures." The body temperature of the birds and mammals being high, and the covering of the hair or feathers rendering them proof against the extremes of heat or cold, we can see that there is a coincidence between this and the fact that these classes began to increase in numbers towards the end of the Mesozoic, and especially at the opening of the Tertiary, when the climatic zones began to be established. So also in the case of whales the loss of hair is compensated for by the blubber. Why, however, feathers developed in birds, rather than hair, is a problem no one has attempted to solve, though feathers, of course, better adapt the bird to flight; no flightless birds having such well developed feathers as those capable of extended flight. (See G. Jaeger, Problems of Nature, Translated by Henry G. Schlichter, D.S.C., London, 1897, p. 66.)

It might be suggested that the broad vane-like surface which characterizes feathers as compared with hairs may have been due to the fact that they would better support the body in flight; this difference from scales, as well as their greater lightness, giving this sort of armature an advantage over scales on the one hand and hairs on the other.

*It has also been claimed by J. W. Gregory that the fossil plants of the Greenland Miocene beds may have been drifted from the southward, and that the temperature of the Polar region was not so elevated as Heer had been led to suppose. (*Nature*, Vol. 56, p. 352, 1897.)

The elevation of the West Indies took place at this date, and these islands were peopled from the South American coast. What we already know of the rapid evolution of molluscs, insects and mammals on these islands shows how closely dependent variation and adaptation are on isolation as well as changed topographic and climatic features.

These problems have been studied with great care in the Hawaiian Islands by Gulick, and more recently by Hyatt. As well stated by Woodworth: "With the development of the umbrella-shaped topography of the Island of Oahu the land shells have varied from common ancestral coastal type to valley-cradled, differentiated varieties in the upper and disjointed valleys of this dismantled, volcanic island cone."*

The limits of this address do not permit us to treat at length of the wonderful changes, both geological and zoological, which occurred in western America during the Tertiary. They are now familiar to every one. The geological changes were very great and widespread, as shown by the elevation of the land at the close of the Miocene. Fragments of the Cretaceous sea-bottom, with horizontal strata, occur in the Rocky Mountains at a point about 10,000 feet above the sea. The inland Cretaceous sea was drained off and replaced by a series of fresh-water lakes, beginning with the Puerco, or the lowest Eocene, and ending with the Pliocene lakes.

The most salient biological features of the Tertiary are the apparently sudden appearance, all over the world, of placental mammals, ending, if the deposits are truly Pliocene, with the Java Pithecanthropus, and at the beginning of the Quaternary with paleolithic man.

The question here arises as to what retarded the progress in the mammalian types, although small, generalized, feeble insect-eaters had originated certainly in the Triassic and probably as early as the end of the Permian. We can only account for it by the unfavorable biological environment, by the apparently overwhelming numbers of Mesozoic reptiles, adapted as they were for every variety of station and soil, whether on land, in the ocean, in the lakes and rivers, and even in the air.

When the reptiles became partly extinct a great acceleration in the evolution of mammals at once resulted. There were now upland grassy plains, bordered by extensive forests, which also clothed the highlands, and all the geographical conditions so favorable to mammalian life became pronounced after the Cretaceous seas were drained off.

In his admirable essay on the relation between base-leveling and organic evolution, which we had not read until after planning and writing this address, though following the same line of thought, Mr. J. B. Woodworth suggests that mammalian life in the Mesozoic was unfavorably affected by the peneplain and by reptilian life.

"The weak marsupials or low mammals, which appear in this country with Dromatherium in the tolerably high relief of the Trias, were apparently driven to the uplands by the more puissant and numerous reptilia of the peneplain. Their development seems also to have been retarded." Again he says: "To sum up the faunal history of the Mesozoic alone, we have seen that *pari passu* with the creation of broad lowlands there was brought on to the stage a remarkable production of reptiles, a characteristic lowland life; and we note that the humble mammalia were excluded from the peneplain or held back in their development, so far as we know them by actual remains, during this condition of

*The Relation between Base-leveling and Organic Evolution, referring to J. T. Gulick's article in Proc. Bost. Soc. Nat. Hist., XXIV., 1870, pp. 166-7.

affairs until the very highest Cretaceous. At the close of the Mesozoic the area of the peneplain was uplifted and there came into it the new life. Not only the changed geographic conditions, but the better-fitted mammalia, also were probably factors in terminating the life of the peneplains."*

After the placental mammals once became established, as the result of favorable geographical conditions, of migrations, isolation, and secondarily of competition, the evolution as well as the elimination of forms, as is well known, went on most rapidly. Remains of over two thousand species of extinct mammals during Tertiary times which existed in America north of Mexico have been already described, where at present there are scarcely more than three hundred. This process of specialization involved not only the lengthening of the legs, the change from plantigrade to digitigrade, and to limbs adapted for seizing and handling their prey or food, or for swimming and climbing; the reduction of digits; the evolution of armatures, protective scales, etc.; but, above all, an increase in the mental capacity of the later forms, not only of mammals, but of birds, as shown by the progressive increase in size of their brains; those of certain existing mammals being eight times as large, in proportion to the bulk of the body, as those of their early Tertiary ancestors. This, of course, means that animal shrewdness, cunning and other intellectual qualities, the result of semi-social attrition and competition, had begun to displace the partly physical factors, and in the primates these may have in the beginning led to the appearance of man, a social animal, with the power of speech, and all the intelligent moral and spiritual qualities, which perhaps primarily owe their genesis to increased brain-power.

* *American Geologist*, Vol. XIV., Oct., 1894, pp. 208–235.

The three most specialized types of mammals below men are the horse, the bats and the whales. In the case of the bats, which appear in the Eocene, Nature's experiment with these mammalian aëronauts succeeded to the extent that they still exist in small numbers. Late in the Cretaceous, or very early in the Eocene, competition apparently forced some unknown carnivorous type to take up an aquatic life, and the great success of the incoming cetacean type, resulting in the Eocene zeuglodonts and Miocene Squalodon, may have had an influence on the final extinction of the colossal marine reptiles.

6. THE QUATERNARY PERIOD.

Coming now to the glacial epoch of the Quaternary period, we plainly see that, under the extreme conditions to which as never before, life in the northern hemisphere was exposed how intimate are the relations of geology and biology.

The rise of land at the beginning of the Quaternary, which carried the land and the life on it up into a cooler zone, with a mean temperature so low that the snows remained from century to century unmelted, forming continental glaciers, excited an immediate influence on the life. There were very soon developed a circumpolar flora and fauna, originating from the few Pliocene forms which became adapted to climatic conditions more extreme than ever before known in the world's history. While a few forms thus survived, some must have perished, though the bulk of them migrated southward.

The story told by the Port Kennedy hole, in Pennsylvania, just south of the limits of the ice sheet, is a most striking one. In that assemblage where are intermingled the bones of mammals of the Appalachian subprovince, with certain extinct forms, and those of the tapir and peccary and colossal sloths, adapted to the warmth of the Pliocene

and of the present Central American region, we can realize as never before the immediate effect of a simple though very decided change of climate on organic life.

As a result of the submergence of the land in the north Atlantic and Arctic regions during the Leda or Champlain epoch succeeding, and the consequent amelioration of the climate, there was a return of a portion of the Pliocene species to the vast area thus freed from the presence of land ice.

Another effect of change of climate due to the further upheaval, drainage and drying up of lakes and river sources in the central portions of all the continents was the destruction of forests resulting from the drying-up of the lakes and streams, the formation of vast internal desert regions, with the desert floras and fauna and saline animals peculiar to them ; these are the last steps in geological history of the origination of species, and have been taken almost under the observation of man. In the origin of species adapted to desert areas and to salt lakes, *faunæ relictæ* of the lakes on the elevated plains of Asia, South America, Africa, Sweden and the Great Lake region, we see that geographical isolation and the absence of competition are the primary factors in the case.

In conclusion, it is, from the nature of the case, notwithstanding the imperfection of the geological record, apparent that the fullest, most complete and convincing proof of organic evolution is derived from the past history of life, from paleontology, which involves the fact of geological succession. Looking back for half a century we see that organic evolution is a fact and is grounded and dependent on geological evolution, and the latter on cosmical evolution. Should we ever have to abandon the principle of evolution we should also have to give up the theory of gravitation, the principle of the correlation of physical forces, and also the conception of the unity of nature. All of these principles are interdependent, and form the foundation stones of our modern science.

The rapid summary we have given of the successive changes and revolutions in the earth's history and the fact that they are accompanied or followed by the process of the extinction of the unadapted, and their replacement by the more specialized and better adapted, show that there is between these two sets of phenomena a relation of cause and effect.

Moreover, it cannot be denied that the formation of our solar system in the manner outlined by the founders of the nebular hypothesis, that the progressive changes in geology and the earth's topography, the gradual building-up or evolution of the continents, and the increasing fitness and intelligence of the life on its surface, the final outcome being man, whose physical development was practically completed at the beginning of the Quaternary period, and whose intellectual and moral improvement have, as it were, but just begun—the scientist, as such, can scarcely deny that this process of evolution, along so many lines and involving not only material but mental and moral advances, has gone on in an orderly and progressive way. The impression left on the mind is that all these changes, inorganic and organic, have been purposive rather than fortuitous, the result of the action of natural laws, impressed on matter by an Intelligence and force outside of, but yet immanent in, all things material.

With Hutton, we may say: "We have now got to the end of our reasoning ; we have no data further to conclude immediately from that which actually is. But we have got enough—we have the satisfaction to find that in Nature there is wisdom, system and consistency."

Here, as men of science merely, we may pause and confess our ignorance of the first or ultimate cause of this progressive evolutionary movement pervading the material

universe and, suspending our judgment, assume an agnostic position. But the human mind, even when rigidly scientific and logical, is so constituted that few of us are satisfied to stop here. He who is most capable of daring speculation in the realm of physical or biological or philosophic thought cannot refrain from inquiring into the nature of the first or moving cause, and how the present order of things has been brought about.

As a mere working hypothesis, we are, at least many of us, compelled to assume that the present order of things, material and immaterial, is not self-evolved, but is the result of an Infinite Intelligence and Will giving the initial impulse and dominating as well as guiding and coordinating the progressive changes, whether cosmical, geological or biological. The fact of the survival of the fittest, of the extinction of the unfit, the conclusion that throughout the universe order has arisen from chaos or the undifferentiated, the specialized from the generalized, that the good and beautiful and true have in the past overcome and will continue to outweigh what is unfit and evil in matter, mind and morals, at least strongly suggests that the First Cause is not only omnipotent but all-wise and beneficent. For evolution tends to optimism. Few working biologists are pessimistic. And thus, while science as such is concerned with facts and their relations, we can at the end of this century of scientific effort affirm that it need not be, and is not, opposed to whatever is noble, exalted, hopeful and inspiring in human aspirations, or to the yearnings of the soul for a life beyond the present, for there certainly are, in the facts of the moral and spiritual evolution of our race, intimations of immortality, and suggestions, where absolute proof is naturally wanting, of a divinity that shapes the course of nature.

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REPORTS OF COMMITTEES OF THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

SIXTEENTH ANNUAL REPORT OF THE COMMITTEE ON INDEXING CHEMICAL LITERATURE.

THE Committee on Indexing Chemical Literature respectfully presents to the Chemical Section its sixteenth annual report, covering the twelve months ending August, 1898.

Works Published.

A Bibliography of the Metals of the Platinum Group, Platinum, Palladium, Iridium, Rhodium, Osmium, Ruthenium, 1748–1896. By JAS. LEWIS HOWE. Smithsonian Miscellaneous Collections, 1084. City of Washington, 1897. 8vo. Pp. 318.

This fine volume forms one of the most valuable and comprehensive indexes to an important field of chemical literature produced under the auspices of the Committee since its appointment in 1882. It shows on every page evidence of conscientious and critical skill; the author- and subject-indexes, with which the book concludes, are important features. Its workmanship and the method of presentation of data in type make Dr. Howe's volume a model.

Reference to the Literature of the Sugar-Beet, exclusive of works in foreign languages. By CLARIBEL RUTH BARNETT. U. S. Department of Agriculture. Library Bulletin, June, 1897. 4to. Pp. 9.

This carefully edited contribution to the bibliography of a subject interesting to the chemist as well as to the scientific farmer manifests the activity of the U. S. Department of Agriculture in its Library.

A Chemical Bibliography of Morphine 1875–1896. By H. E. BROWN, under the direction of A. B. PRESCOTT. Completed in Pharmaceutical Archives, Vol. 1, No. 3.

A supplement carries the literature through 1897. The separates contain an index of authors.